節能減碳與作物病害管理研討會 193-202

利用植物免疫力防治病害的現況與展望

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摘　要

植物免疫力乃植物與病原交互作用時，藉由一連串訊息分子傳遞誘發防禦反應，以抵抗病原入侵的能力；亦可藉根圈有益微生物誘導植物免疫力的提升。植物根圈環境中擁有豐富的微生物相，其中植物促生根圈細菌(plant growth-promoting rhizobacteria, PGPR)可激發植物之免疫力，且不會影響植物的生長與發育，甚至具有促進植物生長的能力。已知植物促生根圈細菌可保護植物，避免真菌、細菌、病毒、線蟲等病原的入侵，多數 *Pseudomonas* 及 *Bacillus* 之種類具有此能力，可開發應用於植物病害之生物防治。誘發植物免疫力會因細菌與植物間的辨識造成植物抗病程度不一，選用適當的生物防治菌株始可減少病害之發生，並得降低田間農藥使用量、減少環境汙染及避免病原菌抗藥菌株的產生。

關鍵詞：植物免疫力、有益根圈菌、生物防治

緒　言

近年來環保意識抬頭，施用化學農藥所造成的環境污染問題深受重視。有機農業之推廣與倡導，應用生物農藥以減少或完全替代化學藥劑的使用，已成為當前刻不容緩的目標及發展趨勢。至今，生物製劑已漸漸地被農民所接受，且應用於現今臺灣的農產業。施用植物保護用途之生物製劑，除了能增加植物免疫力，有效地降低病蟲的危害，還能增加土壤肥力，

改良土壤物理性質，甚至改善土壤重金屬污染的問題等；本文主要探討植物根圈菌誘發植物免疫力的作用。

在植物與病原交互作用之初期，病原可否成功感染植物，決定於植物本身是否能快速且正確地產生相關的防禦訊息，誘發適當的防禦反應，以阻礙病原的入侵。植物根圈菌則能激發植物的免疫力，以抵抗植物病原的侵染，降低植物病害的嚴重度。根圈菌中的菌根菌能快速地纏據於植物根系與植物共生，幫助植物吸收水分、礦物質、磷酸鹽類等物質[9]；固氮細菌能吸收大氣中的游離氮供給植物生長所須的氮源[26]，還有一些土棲性有益微生物能促進植物生長並抑制植物病害或蟲害的嚴重發生[11,15,29,33]。因此，藉由生物因子可直接抑制病原危害植物或間接地激發植物抗病的反應[28]。目前已知誘導系統抗病性可區分為systemic acquired resistance (SAR)及induced systemic resistance (ISR)兩大類。SAR為生物因子如植物病原所誘發的全株抗性，非生物因子如水楊酸及其功能類似物可誘發類似之抗病性，其中以病原侵入植物組織造成壞疽病斑時所誘導的系統抗病性最強[5]。水楊酸(salicylic acid, SA)為訊息傳導物質，經由NPR1 (nonexpresser of PR genes)蛋白質調控表現病程相關蛋白質(pathogenesis-related proteins, PRs)；反之，若將水楊酸羥化酶 (salicylate hydroxylase, NahG)之基因轉入植物體內使其大量表現，會抑制水楊酸的累積，導致SAR路徑中止且不會表現PRs[27]。

ISR 則與群聚於植物根圈之非致病性有益微生物有關，如許多根圈細菌可促進植物生長，並能誘發植物之免疫力，但不會在根部或葉部造成明顯的病徵[31]。許多根圈菌可有效地避免病原如真菌、細菌、病毒及線蟲的入侵[10,19,25,34]，如預先噴灑 *Bacillus pumilus* 203-6 或 203-7 菌株及 *Bacillus mycoides* Bac J 菌株之細菌懸浮液於甜菜葉面後，可降低 *Cercospora beticola* Sacc.引起甜菜葉斑病之危害嚴重度[2,3]。另外，如自臺灣百合根圈採集土壤樣品，以土壤稀釋平板法分離及純化細菌菌株，將不同菌株細菌懸浮液澆灌於臺灣百合根圈，篩選對百合植株沒有負面影響，甚至略有促進生長作用之菌株，在臺灣百合及葵百合上進行溫室防治試驗，並於臺灣百合、葵百合及阿卡波克百合上進行實地田間防治試驗，結果顯示皆能有效地降低

灰黴病之嚴重度及減少病斑的數目，顯示可以應用根圈細菌保護百合之地上部組織，避免灰黴病的危害[17]。

有益微生物誘導植物抗性之機制

目前有益微生物之應用最為廣泛的種類有假單胞菌屬(*Pseudomonas* spp.)、桿菌屬(*Bacillus* spp.)等細菌。螢光假單胞菌(*Pseudomonas fluorescens*)的鞭毛蛋白(flagellin)或脂多醣(lipopolysaccharides)可誘發植物之抗病能力[4,20]。從 *P. fluorescens* 純化之鞭毛蛋白及脂多醣可誘導阿拉伯芥、番茄及大豆免疫力的增升；反之，將鞭毛蛋白及脂多醣突變後則無法刺激植物產生抗病的能力。施用枯草桿菌(*Bacillus subtilis*)於植物根系，此細菌分泌 surfactin、fengycin 等脂胜肽類(lipopeptides)抗生物質，激發大豆或番茄免疫力的提升，可使地上部組織得以對抗灰黴病菌(*Botrytis cinerea*)的侵染[21]。

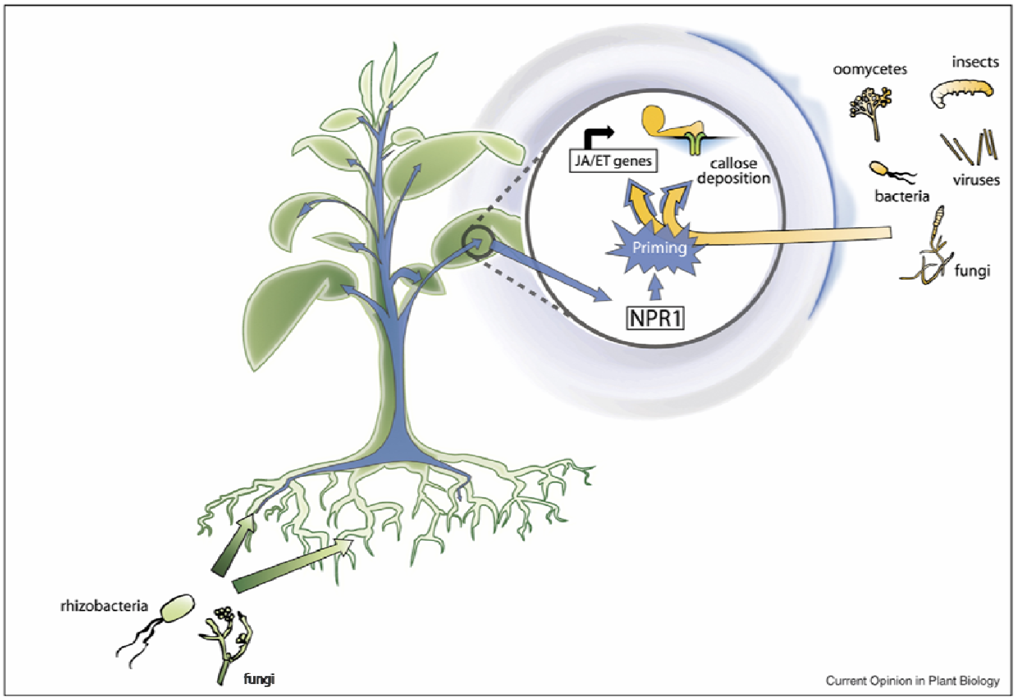
非致病性之根圈細菌於植物根系可以抑制病原菌族群的增長，因而能有效地預防地下部及地上部病害的發生，其可能之生物防治機制有：(1)鐵離子嵌合物(siderophores)的作用：限制病原菌吸收土壤中的游離二價鐵離子，影響病原菌的生存能力而致死亡[18,23]；(2)競爭作用(competition)：在營養上可和病原菌互相競爭環境中或植物根部分泌的營養物質，使病原菌無法得到養分或生長之重要因子，造成病原菌死亡[18]；(3)抗生物質的作用(antibiosis)：許多根圈拮抗細菌具有產生抗生素的能力，如2,4-diacetyl phloroglucinol (Ph1)、HCN、butyrolactones、ammonia、kanosamine、2,4-diacetylphloroglucinol (DAPG)、oligomycin A、oomycin A等抗生物質，可直接抑制病原菌生長及真菌孢子的發芽，降低病原菌族群密度及對植物的危害[13,14]；(4)誘導植物產生抗病性(induction of systemic resistance)：經由根部處理根圈細菌，使未處理根圈細菌的根組織及葉片，對病原的感染具有抵抗性。*Pseudomonas aeruginosa* 7NSK2 於番茄根系生長時會釋放出鐵離子嵌合物 pyochelin 及抗生物質pyocyanin，用以誘導番茄產生系統性的抗病能力[1]；另外在番茄上，根圈菌*Serratia liquefaciens* MG1及*Pseudomonas putida* IsoF 可纏據其根系，產生N-acyl-L-homoserine lactones (AHL)，並誘

導番茄產生系統性抗病的能力，減緩*Alternaria alternata*引起葉斑病的嚴重度[24]。

根圈菌誘導植物之抗病潛能

預先施用根圈菌於植物根系，再接種植物病原，始能有效地誘發植物系統性抗病反應，如此激發植物之抗病潛能，以‘priming’稱之[6]。Liu 等人在研究與植物共生之菌根菌，發現植物被誘發之基因表現非常地微弱且不易察覺[16]；另外，應用微陣列技術探討螢光假單胞菌誘導阿拉伯芥抗性的表現，發現大多數具差異性表現之基因與逆境反應相關，且須受到病原侵染後，才會表現出已知的抗性基因[32]。因此，根圈菌對植物抗病潛能化的促進能力，有助於植物對病害之免疫力提升。

Park 與 Kloepper 在阿拉伯芥上的研究指出，利用*PR-1a*啟動子與ß-glucuronidase (GUS) 報導基因融合，以農桿菌轉型至阿拉伯芥，利用九種不同根圈細菌澆灌於阿拉伯芥轉型株，進而偵測GUS活性。結果指出此九種不同根圈細菌皆可誘導不同程度*PR-1a*基因的表現，並能減少*Pseudomonas syringae* pv. *tabaci*引發煙草野火病的嚴重度[22]，顯示根圈細菌可誘發已知SAR基因表現。但也有其他例子指出，利用*P. aeruginosa* 7NSK2可以誘導煙草產生系統抗病性，減少煙草嵌紋病毒在煙草上造成病斑的大小，此與7NSK2菌株產生水楊酸有關，但7NSK2菌株不會使*PR1a*基因表現[7]。另外以微陣列技術分析螢光假單胞菌處理的阿拉伯芥根及葉片基因表現，結果在根部鑑定出97個基因被誘導表現，其中包括了抗病、代謝及訊息傳遞等基因，但是在葉部卻沒有偵測到任何一個基因可被螢光假單胞菌所誘發而表現；當預先處理螢光假單胞菌，再接種*Pseudomonas syringae* pv. *tomato* DC3000菌株，則發現有少部分基因被誘導表現且皆循茉莉酸與乙烯訊息傳遞之路徑[32]。故不同根圈菌所誘發之植物抗病性可能有不同的反應，有些根圈菌會誘導植物表現似SAR路徑之*PR*基因，有些則不會誘導植物表現已知的*PR*基因，推測根圈菌所誘導之ISR抗病性會因不同細菌與植物間的辨識表現出不同的抗病反應，且其實質的抗病機制仍待釐清。



圖一、利用根圈促生菌提升植物免疫力之訊息傳遞模式

Fig. 1. Model of signaling transduction pathway of plant immunity induced by plant growth-promoting microorganisms in the rhizosphere.

結論與展望

根圈菌能有效地使植物表現抗病反應，減少病害發生的機率及嚴重度，乃因根圈菌能與植物建立良好的互動關係，且不會傷害植物正常的生長與發育。不同根圈菌在不同植物上造成程度不一的抗病能力，如螢光假單胞菌 WCS374 菌株能有效地誘導蘿蔔對抗鐮孢菌(*Fusarium* sp.)的危害，但卻不能成功地誘導阿拉伯芥產生系統性抗病的能力；相反地，螢光假單胞菌 WCS358r 菌株可以成功地誘導阿拉伯芥產生抗病性，但卻不能誘導蘿蔔表現抗病能力，然 *Pseudomonas fluorescens* WCS417r 則可以同時誘導阿拉伯芥及蘿蔔表現抗病的能力[30]。故選擇適當的生物防治菌株方可減少病害發生，始能降低農藥使用量及避免病原菌抗藥菌株的產生。

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Activation of Plant Immunity for Control of Plant Diseases

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ABSTRACT

Interactions between plant and pathogen can induce plant immunity by a series of signal transduction and activation of plant defense responses, giving resistance to pathogen attacks; in addition, plant immunity can be activated by beneficial microorganisms present in the rhizosphere. In the plant rhizosphere, there are plenty of organisms; among them, plant growth-promoting rhizobacteria (PGPR) are able to activate plant immunity, and are capable of promoting plant growth and development without adverse effect. PGPR are able to protect plants from attacks by different kinds of pathogens, including fungi, bacteria, virus, and nematode. Many species of *Pseudomonas* and *Bacillus* with plant growth-promoting activity can be applied for the biocontrol of plant diseases. Activation of plant immunity depends on the recognition of bacterium by the plant and the level of disease resistance being induced. Use of suitable biocontrol agents can improve disease suppression effect; it would also decrease the amount of agrochemical applied, environmental pollution and the generation of drug resistant strains of pathogens.

Key words: Plant immunity, beneficial rhizobacteria, biocontrol.